Technology I / II
Architecture 207-309 (undergraduate sophomore year, also open to non-majors)
Architecture 507-509 (graduate option 1 first year, open to non-majors with approval)

Instructor: Christof Spieler, P.E., LEED AP

"To define it rudely but not ineptly, engineering is the art of doing for 10 shillings what any fool can do for a pound."

- Arthur Wellesley, 1st Duke of Wellington

At its most fundamental, structural engineering is simple: will a building stand up or won't it? Every structural problem comes down to a ratio of load over capacity: if that ratio is 1.0 or less, the structure works; if it is more it doesn't. Thus, unlike architecture, engineering promises certainty: there are indisputably wrong answers.

This certainty grants engineers an aura of authority. Engineers are respected in a way architects are not because their statements are seen as statements of fact. The ability to say

emphatically that something will not work -- the ability to quantify rather than qualify -- can win nearly any argument. This certainty introduces an imbalance to the relationship between architect and engineers, creating the perception that engineers' statements are fact-based while architects' are merely expressions of desires.

In reality, engineering does not promise a right answer. All engineering can prove is that a certain design is wrong. The vast variety of buildings that have, in fact, not collapsed shows that there are innumerable structural responses to any given problem that will create a capacity that exceeds the load, and that there is a structural solution to nearly any problem.

Thus the basic equation that grants engineers their authority is rarely the limitation of what we can build. The forces of gravity, wind, and earthquakes, and the strengths of materials, do not create any meaningful limitations to architecture. We can build taller than the world's tallest building, span longer than the world's bridge, and cantilever far enough to impress anyone.

The real limit on the structures we build -- and the most powerful force that a structural engineer must confront -- is economics. The height of skyscrapers is set by land prices, lease rates, labor costs, commodity prices, and the availability of capital. The span of bridges is set by federal transportation policy, local funding priorities, and political deals.

We can't understand the economics of structures if we don't understand the supply chain behind them. A pretensioned precast concrete girder bridge built in Houston in 2014 is, just like a wooden covered bridge built in rural New England in 1810: a rational response to the availability of materials, the infrastructure of support facilities, the cost of labor, and the limitations of transportation. The greatest innovation in the history of architectural structures was not the advent of steel and concrete but rather the industrialization of construction. Today, virtually all buildings, regardless of their structural system, are built using mass produced materials produced to standardized specifications.

In the context of a design process, money is as powerful and immovable a force as gravity. A structural engineer can end a discussion as effectively by saying "that is not cost-effective" as by saying "that will not stand up." These discussions inevitably drive building design towards the ordinary. The structural grid is a powerful architectural idea. But the structural grid is equally powerful as an economic idea. A series of repetitive beams of equal length is less expensive to calculate, less expensive to produce, and less likely to lead to expensive field fixes than an irregular structure. This truism holds regardless of the prevailing architectural discussions of the day, and, in a capitalist society, it inevitably shapes those discussions. Corporations adopted modernism in the 1960s because of its associations with progress efficiency, and rationality, but they also adopted modernism because it was inexpensive to replicate.

Thus, the engineer's command of gravity and money grants disproportionate influence over the design of buildings. An architect can react by fighting back, by attempting to assert the importance of less quantifiable aims. Alternately, an architect can choose to appropriate those powerful forces to the ends of architecture by understanding how structures are designed, fabricated, and erected.

Today, we are in the midst of a new revolution in architectural structures. Computers have

transformed the visualization, simulation, documentation, and fabrication of buildings. BIM models, linked to structural analysis models and exported to computer-driven fabrication shops, have enabled an unprecedented level of mass customization within established logistics systems, allowing architects to create complex and nonorthogonal structures within the limitations of gravity and cost.

The aim of this course is to equip architects with the knowledge to lead the structural design and construction process, rather than allowing the engineer and the contractor to limit the architectural design. Architects do not need to be able to engineer a structure, but they need to be able to have an intelligent discussion about structural design and fabrication, to push back when required, and to conceive structural solutions that support their architectural ideas.

Over the course of two semesters, we start with the simplest and most common of structural systems: the pinned frame. Then we begin to transform this frame, extending spans, introducing continuity and fixed connections, warping geometry, and finally blending the frame into the skin. By the end, we'll have seen covered structural systems that will enable everything that could be conceived in an architectural studio.

The intent of this two-semester sequence is to introduce students to structural concepts that can be applied to a wide range of buildings. These concepts are placed in a context of material properties, natural forces, industrial systems, construction techniques, economic imperatives, sustainability, following requirements, and architectural ideas to examine what factors drive the selection of structural systems.

Lectures focus on structural concepts, illustrated with wide variety of built examples from throughout the world. The final exams at the end of each semester cover the same material as the lectures. Tutorials will focus on quantifying structural behavior through calculation; supported by 8 homeworks throughout each semester. Field trips will include construction sites and fabrication firms. Each semester includes a design project to design, detail, and calculate a structural system for a selected program. The proposed system is critiqued in class for its feasibility, economy, and architectural potential. Independent research is expected. Design software is an integral part of the course. Rhino will be used for design, coupled with Karamba, a powerful structural analysis package that will also be used for the final projects.

Sustainability topics, including use of natural resources, energy consumption, transport, and reuse, are emphasized and are integrated throughout the course.

ARCH 207/507: The Frame (Fall 2014)
The first semester explores the trabeated frame as a structural system.

Introduction: history of structural engineering, the language of structures
I. Walls
    Gravity Loads
    Load bearing walls
    Masonry
II. Beams
    Beams
    Moment
    Wood
III. Pinned frame
    Pinned frames
    Steel
    Compression
    Foundation
    Earthquake and Hurricane loads
    Shearwalls and braces
IV. Truss
    Trusses
V. Highrise
    The history of highrise

Conclusion: economics

ARCH 309/509: The Shell (Spring 2015)
The second semester explores the consequences of continuous structures and rigid connections, then moves on to non-orthogonal and undifferentiated systems.

Introduction: the tyranny of the grid
VI. Rigid Frame
    Rigid frames
    Concrete
VII. Slab
    Slabs
    Post-Tensioning
VI. Curved Frame
    Curved
    Connections
X. Shell
    Arches/Domes/shells
    Tensile
XI. Integrated skins
    Monocoque
    Tiltwall, SIP, and ICF
    Tall walls
    Diagrid/shear plane
    Hybrid systems
VIII. Longspan
    Longspan buildings
    1000 ft bridges

Conclusion: Architect vs. Engineer

Upon completion of this sequence, a student is expected to:

- Understand the basic principals of structural behavior.
- Understand the properties, behaviors, and attributes of common structural materials.
- Understand the process of design, fabrication, and erection of structural systems.
- Be able to select a reasonable structural system for a particular building.
- Be able to roughly size members for a structural system.
- Be able to detail common structural systems.

Owlspace and Email
Class schedules, assignments, and announcements will be posted on Owlspace. Students are expected to check Owlspace for updates. All students are expected to check their Rice email accounts. Individual communications may come through email.

Grading (207/309)

Class grade is based on:

- A structural system research project (10%) [100 points]
- A three-part design project (30%) [150 points part II, 150 points part III]
- A final exam (30%) [300 points]
- Homeworks (20%) [8 @ 25 points each]
- Attendance (10%) [100 points]

Grading (507/509)

Class grade is based on:

- A structural system research project (10%) [100 points]
- A three-part design project (30%) [150 points part II, 150 points part III]
- A final exam (30%) [300 points]
- Homeworks (20%) [8 @ 25 points each]
- Attendance (10%) [100 points]

Grading scale

The total number of points will be noted on each assignment, on the project, on attendance, and on the exam. The preliminary grading scale is as follows:
90% or above: A
80%-89%: B
70%-79%: C
60%-69%: D
59% or below: F
This range may be adjusted downwards but not upwards.

Homeworks

Homeworks will be based on calculations. They will be tied to class content and readings but will not be directly explained in class. All homeworks can be re-submitted (once) after being graded: a student can redo whatever they got wrong and turn in again for full credit. This is only valid if the initial submission is on time and complete (though incorrect). If a student does not follow the requirements for how to submit the assignment (turns in a .jpg instead of a pdf, turns in multiple pdfs instead of one) they will be graded 0.

Final exam

The exam will be based on lecture content. It will include short answer and essay questions. The powerpoint slides shown in class will be posted for exam review, and a review exam (with different questions than the exam) will be posted as well. The exam is on Owlspace; it is a take-home and can be taken any time between the last day of class and the end of finals period.

Project

Each semester's project consists of the structural design of a building for an assigned program. Each will be assigned in three parts. The first consists of a meeting with the instructor, the second of a juried design presentation, and the third of a complete set of calculations using RISA.
207/507 students will be assigned an additional project consisting of a report on an assigned structural system based on research and calculation.

Attendance

The attendance portion of the class (10% of the class grade) will be graded as follows:-2 or fewer absences - full credit-3 or 4 absences - 50% credit-more than 4 absences - no creditAccommodations may be made for illness or academic-related absences. If you will miss class for these reasons, email me (spieler@rice.edu) with "absence" in the subject line before class starts.It will be difficult to do well on the exam without attending the lectures. Any student who will miss a class can contact the instructor for alternatives.

Honor code
The extent of collaboration permitted on each assignment, project, and exam will be indicated with that assignment, project, or exam.

Accommodations for disability
Any student with a documented disability seeking academic adjustments or accommodations is requested to speak to the instructor during the first two weeks of class. All such discussions will remain as confidential as possible. Students with disabilities will need to also contact Disability Support Services in the Allen Center.

Contact info
Christof Spieler may be reached as follows:
email: spieler@rice.edu
mobile phone: (832) 687-1613

Prerequisites
This class is open to architecture majors as well as non-majors. There are no prerequisites.

Textbook
The following texts are assigned for the class:

- "Architectural Structures," Wayne Place, 2007
- "Understanding Steel Design: An Architectural Design Manual," Terri Meyer Boake, 2011

The following text is recommended:

- "The Function of Form," Farshid Moussavi, 2009.

Texts may be purchased on Amazon.

Additional readings will be distributed.